THE NICKEL BULLETIN

A SUMMARY OF CURRENT INFORMATION ON NICKEL

MARCH, 1951

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ABSTRACTS OF CURRENT PUBLISHED INFORMATION ON NICKEL AND ITS ALLOYS

GENERAL

Time-Temperature-Transformation Data: Reference Bibliography

F. R. MORRAL: 'Mid-Century Reference of Heat Treating.' *Iron Age*, 1951, vol. 167, Jan. 4, pp. 267-8, 448-58, 460-2.

A unique classified *bibliography* of papers relating to time-temperature-transformation. The lists are presented alphabetically, in order of the author's name (or, in the case of anonymous items, of the first word of the title) and a classified key shows which items are associated with the various aspects of the subject.

The subject classification is as follows: historical; surveys and general reviews; TTT diagrams (for ferrous and non-ferrous materials); austenite transformation; isothermal heat-treating practice; continuous cooling; hardenability.

Colouring of Metals and Alloys

See abstract on p. 49.

NICKEL

The Nickel Industry of Ontario

THE STAFF OF INTERNATIONAL NICKEL CO., INC.: 'Ontario Nickel Industry.' *Reprint from Canad. Mining Jnl.*, 1950, vol. 71, Nov., pp. 134-43.
Issued by International Nickel Co., Inc., 1951.

The Ontario nickel industry, which furnishes 80 per cent. of world nickel supply, dates its history from mining which was begun at Lady MacDonald mine in 1885. From that date until January 1950 a total of 172,317,615 tons of ore had been produced in this area, by the 41 mines which have been operated. The largest of these is the INCO Frood-Stobie mine, which has supplied 93,963,000 tons.

This article traces the history of the Ontario nickel industry from the earliest days, noting the extent of the operations undertaken in the past, and current activities; the geology of the district, the nature of the ore mined and the mode of its occurrence; the work of the early prospectors and the establishment of the original mining companies; mining methods used in the early days and their gradual modification and improvement, and the lines of mining research which have led to modern methods of working. Milestones in matte production, and recent improvements in extraction practice introduced by the International Nickel Company of Canada are reviewed. These have culminated in the introduction, in September, 1948, of a new process for the separation of the copper, nickel and precious metals in the matte, by subjecting the matte to controlled cooling, flotation and magnetic separation. The change-over to this method, from the earlier (Orford) process, was completed in July 1949, and the entire output of the Copper Cliff smelter is now handled by the new process. Reference is also made to another recent development of unusual interest, the flash-smelting of nickel- and copper-sulphide concentrates with oxygen. An oxygen plant and initial flash-smelting copper furnace are under construction at the Copper Cliff plant, and will be in operation during the present year. This change will result in lower coal requirements, and allow increased output of sulphuric acid, and the production of liquid sulphur dioxide from furnace exhaust gases, at the plant of Canadian Industries Limited, which is in the near vicinity of Copper Cliff.

The total growth of the Ontario nickel industry is illustrated by the fact that whereas in its initial four months of operation the first blast furnace at Copper Cliff (some 60 years ago) produced 170 tons of nickel, during the past 10 years the Ontario nickel industry's sales have exceeded 100,000 tons of nickel per annum.

The Nickel Industry, 1929-1949

SIR WILLIAM GRIFFITHS: 'The Nickel Industry: Twenty Years On.' *Reprint of paper to Fourth Empire Mining and Metallurgical Congress*, 1949.
Published by International Nickel Co., Inc.; 50 pp.

For scope of this paper see *Nickel Bulletin*, 1949, vol. 22, Nos. 8-9, pp. 132-3. The reprint is amplified by charts showing estimated world nickel production, 1850-1949, published prices of metallic nickel 1840-1949, and metal prices 1903-1949 (tin, nickel, copper, lead and zinc).

Raney Catalyst Prepared from Nickel-Magnesium Alloy

J. N. PATTISON and E. F. DEGERING: 'Some Factors Influencing the Activity of Raney Nickel Catalysts. I. Preparation of Raney Nickel from Nickel-Magnesium Alloy.' *Jnl. Amer. Chemical Soc.*, 1950, vol. 72, Dec., p. 5756.

Preparation of Raney nickel from nickel-magnesium alloys has been the subject of three patents (*French Pat.* 844,783 and *U.S. Pats.* 2,326,275 and 2,328,140), but none gives full details of method of preparation or of the activity of the resulting catalyst.

The present note (extracted from a thesis presented to Purdue University) reports that catalysts comparable in activity with the Pavlic and Adkins W.6 grade can be prepared from nickel-magnesium alloy, using an acetic-acid wash. Full details of procedure are given.

The observations made indicate that the mesh size

of the alloy, and the amount of acid used in the activation step have very little effect on the activity of the catalyst, but that the amount of nickel in the alloy, and the method of washing, are highly important factors. A catalyst prepared from an alloy containing 30 per cent. by weight of nickel was only half as active as one prepared from a 50 per cent. nickel alloy. If the acetic-acid wash is omitted, the resulting substance will not reduce styrene at all under the experimental conditions used.

powder, and is a measure of the rate of density increase with pressure. In the present work the dependence of L on particle size, for carbonyl nickel powder, and the effect of compact height on the relative density, D*o*, were investigated, using both single- and double-action dies. Four powders were used, details of which are given in the table below:—

Results show that the pressing moduli do not vary appreciably with particle size, except when there is a marked difference in apparent density for a certain

Powder No.	Screen Size (mesh)	Remarks	Apparent Density, g./c.c.
1	+60	granular, containing large flakes sometimes 1 mm. across	3·12
2	+100; −60	granular powder with small flakes	2·26
3	+120; −100	granular powder	—
4	−325	fluffy powder	2·49

size of powder. Differences in die-wall friction between single- and double-action dies appear to be unimportant. Although the contact area of the powder against the die is different for each size of powder, all powders must be rapidly consolidated; frictional area for a given size of compact therefore varies only slightly with size of powder.

The data obtained show the same dependence of density on die-wall friction as is indicated by the pressing moduli.

Determination of Traces of Nickel in Catalyst Materials

D. D. HARMON and R. G. RUSSELL: 'Impurities in Catalyst Materials.' *Analytical Chemistry*, 1951, vol. 23, Jan., pp. 125-8.

Many catalyst materials used in the oil industry are composed of an aluminium-silicate matrix containing several minor impurities. During service the activity of the catalyst decreases to a point at which it is no longer commercially feasible to continue its use: simultaneously a progressive increase in metallic-impurity content occurs, attributable to pick-up of metals present in the oil, or from equipment.

Determination of such impurities by wet chemical methods is laborious and time-consuming; chemical determination of elements present in amounts less than 0·1 per cent. is also relatively inaccurate. This paper describes a spectrochemical method which, on very small percentage contents, will give results precise to within ±10 per cent. of the amount present. It uses the alternating-current-spark form of excitation and a briquetted-pellet sample.

Pressing of Nickel Powder

H. LIPSON: 'On the Pressing of Nickel Powder.' *Powder Metallurgy Bull.*, 1950, vol. 5, No. 4, pp. 52-7.

In 1938 Balshin reported an empirical relation between the pressure applied to a compact and the relative volume of the compact:—

$$\ln P = LV_o + C,$$

where P = applied pressure

$V_o = V/V_k = \frac{\text{volume of pressed compact}}{\text{volume of massive metal}}$

L = a constant called the 'pressing modulus'

C = a constant

In this equation the equivalent relationship $D_o = d_k/d$ = density of massive metal/compact density may be substituted for V_o. The pressing modulus L is dependent on the structure and composition of the

Maintenance of Clad Materials

See abstract on p. 65.

Colouring of Metals and Alloys

C. HARRIS: 'Colouring Copper and Copper Alloys.' *Metal Industry*, 1951, vol. 78, Jan. 12 and 19, pp. 23-5, 43-4; 'Colouring Miscellaneous Metals.' *ibid.*, Jan. 26, pp. 71-3; 'Methods of Treatment for Iron and Steel Smallware.' *ibid.*, Feb. 23, pp. 143-6.

The author has selected, from the many existing formulae for colouring of metals and alloys, some of the methods which have proved capable of giving consistently satisfactory results.

In the section relating to copper and copper alloys, chemical-sulphide- and oxide-type finishes are described, with detailed instructions for procedure. The second section covers the colouring of silver, tin, gold, zinc, cadmium, nickel, and chromium.

With regard to nickel the following comments are made: 'Nickel is a metal which has highly coloured salts, but is itself singularly unresponsive to colouring. The high reflectivity of nickel makes it possible, however, to attain the finest colours by the lead-oxide film of the lead-acetate hypo-immersion process and by the Elkington electrocolouring method, details of both of which are given (Jan. 19, pp. 43-4). It is possible to generate a green patina on nickel and plated articles by controlled corrosion in hydrochloric acid atmospheres, but the methods have neither decorative

nor corrosion-proof properties. Various sulphide solutions, notably barium-sulphide solutions, will impart a thin golden appearance, but there appears no evidence that it has decorative value.

'Persulphates appear to have a blackening effect; a solution quoted by H. Silman gives satisfactory results: ammonium persulphate 2 lb.; sodium sulphate 1 lb.; ferric sulphate 1½ oz.; ammonium sulphocyanide 1 oz.; water 1 gall. Temperature 65°F. (18°C.); pH 1-2.' The section on colouring of iron and steel reviews methods for production of temper colours, and for blackening, phosphate coatings, hot tinning and hot galvanizing.

ELECTRODEPOSITION AND OTHER COATING METHODS

History of Nickel Plating

R. J. MCKAY: 'The History of Nickel Plating Developments in U.S.A.' *Plating*, 1951, vol. 38, Jan., pp. 40-4, 57; Feb., pp. 147-50, 155-6.

The year 1951 marks the 200th anniversary of the isolation and naming of the element nickel, by A. F. Cronstedt. In this connexion, a review has been made of the development of nickel plating in the U.S.A., where, as elsewhere, the plating industry accounts for a large proportion of the annual consumption of nickel.

The history of the subject is reviewed, from the days of Faraday to the present time, dealing primarily with periods and events in which discovery and inventions have affected, or have been affected by, commercial development, rather than with technical or commercial phases of development. The stages, designated 'milestones', began with the introduction of commercial plating with cast nickel anodes and double-salt baths, by Isaac Adams, in 1865, the circumstances of which are described. Later events of outstanding importance, to which special reference is made, are: the mechanical generation of current (1874); addition of boric acid (1878); the hot nickel sulphate/chloride/boric acid (Watts) bath (1916); introduction of pH control (ca. 1921-22); advent of chromium plating (1920-1925); introduction of bright nickel (1932-1937).

Commenting on more recent developments and the status of nickel plating to-day, reference is made to the important contribution to progress made by research carried out by suppliers, and to the work of technical societies in the plating field. In this connexion the co-operative tests carried out under the aegis of the American Society for Testing Materials, the American Electroplaters' Society and the National Bureau of Standards have been of major importance. Research projects now under prosecution by the American Electroplaters' Society are carrying the developments still further, from both the theoretical and practical points of view. Specifications drawn up by the A.S.T.M. and other organisations have done much to advance the cause of the nickel-plating industry, but it is felt that much remains to be done in making both platers and users 'specification-conscious'. Other items of recent progress to which specific reference is made in the review include high-current-density plating, developments in building-up processes, plating for resistance to chemical corrosion, and the application of electrodeposition for production of electroformed parts.

Modern trends in the U.S.A. (and elsewhere) would appear to be in the following directions: reduction of polishing and buffing labour; better protection at lower cost; more uniform distribution of metal; consolidation of experience into specifications; publication and discussion, in place of old-fashioned secrecy.

Copper Undercoats to Nickel-Chromium Electrodeposits

B. B. KNAPP and W. A. WESLEY: 'The Effect of Copper Undercoats on the Protective Value of Nickel-Chromium Coatings on Steel.' *Plating*, 1951, vol. 38, Jan., pp. 36-8, 45-8, 54-6: disc., p. 56.

The history of argument and experiment with regard to the value of copper undercoats is comprehensively reviewed, as an introduction to a report of an extensive series of tests made by the authors.

It is noted that a serious attempt to settle the copper controversy is being made by the terms of the A.S.T.M. atmospheric-exposure tests now under way, which provide for the following variables: total plate thickness from 1·0 to 3·0 mils (25μ to 76μ); nickel thickness from 0·5 to 3·0 mils (13μ to 76μ); copper undercoat thickness from 0·1 to 1·5 mils (2·5μ to 38μ); buffing of the undercoat; type of nickel deposit, including bright, semi-bright, and buffed dull nickel; heat-treatment of nickel deposits; type of steel base, and six types of atmosphere, namely, industrial, heavy industrial, rural, seacoast, semi-tropical, and an industrial atmospheric test accelerated by periodic wetting of the panels with a solution of sodium chloride.

The present authors consider that published data resulting from the A.S.T.M. tests up to 1949 justify the following conclusions:—

(1) In a comparison of coatings of the same total thickness, those which include a substantial fraction of copper have less protective value than those free from copper; the greater the per cent. copper the poorer the corrosion resistance.

(2) In any given location, the nickel thickness is the only variable studied in these tests which exerts an important influence on the atmospheric-weathering characteristics of the coatings.

(3) When the results in all the atmospheres represented are considered, buffing of the copper undercoat shows no consistent effect upon protective value.

(4) Use of a thin 'flash' copper coat directly upon the steel has a slight beneficial effect in the industrial atmospheres.

The authors' tests (begun prior to the A.S.T.M. series referred to above) were planned to observe the effects of flash and heavier copper undercoats, upon the rust resistance of nickel-chromium decorative finishes on

steel, while at the same time attempting to test a theory postulated in 1945 by Wesley that the corrosion products of copper are themselves corrosive to nickel-chromium coatings. This theory, if proved, would assist in explaining why copper is not equivalent to nickel in such coatings. The known accelerating effect of soluble salts of copper, upon the corrosion of nickel and other metals in acid solutions, might, it is considered, be expected to play a part in the corrosion of nickel-chromium coatings deposited over copper undercoats exposed in atmospheres containing sulphur dioxide. In a pure marine atmosphere, or in salt spray, on the other hand, the liquid phase is neutral in reaction, and copper corrosion products would be insoluble, and therefore harmless. The same line of reasoning would argue that iron corrosion products would be corrosive to nickel, leading to unsatisfactory behaviour of plated steel parts round unprotected edges, drilled holes, or other local sources of rust. The authors' programme was therefore planned to include also experiments to determine the effects of iron rust on the protective value of nickel-chromium coatings.

The panels coated for test (full details of which are given in the paper) were prepared in such a way as to demonstrate, under exposure, (1) the effect of replacing a large proportion of nickel with copper; (2) the influence of corrosion products draining over the plated surfaces; (3) the alleged beneficial effect of a flash undercoating of copper (on both clean steel and on steel pre-rusted before cleaning and plating). Control panels represented a perfectly clean steel surface prepared by anodic sulphuric-acid treatment before plating.

Exposure tests comprised: (1) normal exposure in Bayonne atmosphere, (2) the salt-accelerated test devised by Phillips and Clifton to simulate the effects of using salt on streets in winter, and (3) standard salt-spray tests. The hot-water porosity test was also applied. The basis material was a steel of S.A.E. 1085 type.

From the results of the various series (individually reported) the following main conclusions are drawn:

Substitution of copper for three-fourths of the nickel in a 2-mil (51-μ) coating had a detrimental effect on the corrosion behaviour of nickel-chromium-plated steel panels, in all exposure tests. The effect was most clearly marked in the accelerated atmospheric exposure, where the copper-nickel-coated panel was completely covered with crater rust spots and rust stain. The difference was less pronounced in the salt-spray and normal-atmospheric exposures, but the all-nickel coating was the more resistant to blistering and crater rusting.

Interposing a flash of copper between the steel and the nickel exerted a beneficial effect for a short time in the atmospheric exposures, but this effect was not lasting. After one year's exposure the copper appeared to have accelerated the corrosion of the iron at pores in the nickel, larger crater rust spots having formed on the panels with the copper undercoat. In the hot-water test a flash of copper was markedly beneficial.

Rusting of the steel base prior to plating adversely affected the protective value of the copper-nickel coatings, but improved that of the all-nickel coatings. The effect was, however, small, and did not persist in the two atmospheric exposures.

Anodic sulphuric-acid pre-treatment of the steel gave results only slightly superior to those obtained by the acid-dip procedure. In the hot-water test, however, the anodic method was to be preferred.

Contact with copper- and with iron-corrosion products accelerated deterioration of the panels; copper appeared to have the greater effect in the atmospheric tests, iron in the salt-spray test.

The nature of the pitting occurring in the deposits was influenced by contact with copper- and iron-corrosion products, and the character of the pits observed under any conditions varied according to whether an undercoat of copper was present or not.

In discussion, W. M. PHILLIPS presented a graph showing the results of inspection of plating on typical parts from automobiles, after prolonged service under varying conditions. His findings, contrary to those based on the panel experiments reported by the authors, are interpreted as 'leading to the inescapable conclusion that the nickel-chromium-plated and the copper-nickel-chromium-plated parts behaved in exactly the same way and that there is no reason to prefer the one to the other'.

It is suggested that the variations are indicative of the different treatments undergone by the test panels and the car parts, a noteworthy difference being the fact that the panels received, while under exposure, no wiping and no oiling.

Economies in Nickel permitted by B.S. Plating Specification

Metal Industry, 1951, vol. 78, Mar. 2, p. 165.

In view of the shortage of nickel which has developed recently, a special meeting of Committees of the British Standards Institution concerned with the preparation Standards relating to electroplated coatings of nickel was held in order to determine what steps should be taken.

The meeting was unanimously of the opinion that B.S. 1224, 'Electroplated Coatings of Nickel and Chromium on Steel and Brass', the only Standard at present published in relation to such coatings, should not be amended, but that a memorandum should be issued drawing attention to the provisions of the Standard, which enable the amount of nickel used to be reduced.

This memorandum (*vide infra*) has now been published, and will be inserted in all copies of B.S. 1224 sold.

> 'In view of the present shortage of supplies of nickel, and the importance of making the most efficient use of the supplies available, attention is drawn to the definition of the significant surface for plating on page 5 of this British Standard, which enables the manufacturer, by agreement with the purchaser, to reduce the surface to be coated in accordance with the Standard.

'Attention is also drawn to the Note, on page 7, relating to standard classifications:—

Ni 8S and Ni 5S

according to which the minimum deposit thickness may be a composite deposit of nickel and copper, provided that the final deposit of nickel is at least 50 per cent. of the whole.'

Production of Ductile Bright-Nickel Deposits

H. G. PATCHING: 'Ductility in Organic Bright Nickels; Effects of Contamination, Plating Conditions and Cleaning Procedure.' *Electroplating*, 1951, vol. 4, Jan., pp. 4-5, 12.

An essentially practical article, dealing with methods of prevention and cure. Among the recommendations made are the following:—

Copper contamination may be avoided by nickel-plating of copper and copper-alloy fittings on the plating plant: removal of annealing scale from brass objects prior to insertion in the nickel bath is imperative. Conditions essential in purification (if metallic contamination has occurred) are succinctly summarized.

Organic contaminants have a 'disastrous' effect on ductility; removal is possible, but prevention of contamination, by cleanliness and careful choice of plant materials, is more economical in time and cost.

Excessive amounts of brightener should be avoided; effect of excess addition is similar to that of organic contaminants.

Increase of boric-acid content, above the normal schedule amounts, has been found useful in increasing ductility, without adversely affecting other properties.

A more scientific control of temperature and pH is urged.

Suitable cleaning sequences are even more important in preparation for bright-nickel plating than in the case of dull nickel. Important factors in this connexion are suggested as being: (1) use of alkaline anodic cleaning for steel, copper, brass, zinc-base and even tin parts, but avoidance of such treatment for high-nickel-content alloys, in order to minimize occurrence of passitivity; (2) avoidance of overcleaning; (3) avoidance of excessive strength in acid dips; (4) use of separate tanks for cathodic/anodic cleaning operations; (5) use of a copper flash in suitable cases, although the writer is of the opinion that 'there is much to be said for nickel plating direct on the base metal'.

Nickel Plating on Aluminium

'Electroplating on Aluminium.' *Electroplating*, 1951, vol. 4, Jan., pp. 16-18.

A brief outline of the nature of the problem involved in electrodeposition on aluminium-base materials is followed by more detailed consideration of the two alternative methods which may be adopted for preparation of the surface, in order to obtain adherent deposits.

(1) The surface of the metal is bared and there is immediately deposited on it an immersion coating of zinc or other suitable metal, to form a base for building up an electrodeposited coating. In this connexion the sequence of operations involving the zincate dip, or plating from a modified zincate solution, is detailed. The significance of the various treatments in this cycle of nickel or nickel + chromium plating is indicated, *alternatively*

(2) Means may be adopted for mechanical anchoring of the electrodeposit to the aluminium surface, without removal of the naturally formed oxide coating.

This method may be operated in two ways:—

(*a*) by chemical etching treatment of the aluminium surface, used in conjunction with production of an immersion deposit, e.g., of brass. Etch solutions recommended by the Aluminum Company of America are described.

(*b*) the second alternative for production of keying is to thicken and strengthen the natural oxide film by anodic oxidation, and to utilize the porosity of the anodic layer to provide a key for the superimposed electrodeposit. In this type of treatment success depends largely on the uniformity of the anodic layer produced, which, in its turn, is vitally influenced by the efficiency of the pre-anodizing pickling treatment. A process described in a recent patent (taken out by the Sperry Gyroscope Company; Brit. Pat. 636,880) is designed to improve and simplify the pickling treatment. The novelty of the procedure lies in the use of nitric-hydrofluoric acid solutions of compositions controlled experimentally to be suitable for individual types of aluminium-base material. For the subsequent anodizing treatment aqueous sodium carbonate is the preferred medium, mainly on account of its detergent effect on the surface of the pickled metal, but also due to the wide latitude in operating conditions which will give satisfactory results. Typical compositions of the solution are quoted. It is claimed that a very high degree of adherence can be so obtained.

Nickel and Nickel-Chromium Plating of Aluminium

R. FYFE: 'Plating Aluminium; Commercial Methods of Depositing Nickel and Chromium.' *Metal Industry*, 1950, vol. 77, Dec. 22, pp. 300-2.

Brief reference is made to two known methods in which the steps involved are shown below:—

(1) *For Commercially Pure Aluminium*

Degreasing in hot, mild alkali cleaner; water swilling; 1-2 minute dip in solution containing 56 oz. nickel chloride, 2 pints hydrochloric acid (sp. gr. 1·18), 1 gallon water (temperature 37°C.); washing; nickel plating.

(2) *For Aluminium Alloys*

Degreasing as in (1); water swilling; 1-2 minute dip in solution containing 3 vols. nitric acid (sp. gr. 1·42), 1 vol. hydrochloric acid (50%); water swilling; nickel plating, with minimum delay.

The main paper comprises a detailed account of an improved method, claimed to be applicable to the plating of both aluminium and a wide range of aluminium-base alloys. It involves polishing, alkaline degreasing, pickling in a 5 per cent. solution of hydrofluoric acid, and subsequent zinc+brass plating, prior to deposition of nickel or nickel + chromium. Full details of procedure are given. The method is claimed

to give sound and adherent deposits on pure aluminium and on most of the commonly used aluminium-base alloys. Experience with this cycle of operations, over a considerable period, has indicated that the figure for rejects due to blistering and faulty adherence can be kept well under 2 per cent.

Deposition of Nickel by Electrochemical Displacement upon Zinc

M. E. STRAUMANIS and C. C. FANG: 'The Structure of Metal Deposits Obtained by Electrochemical Displacement upon Zinc.' *Jnl. Electrochemical Soc.*, 1951, vol. 98, Jan., pp. 9-13.

Copper, gold, nickel and silver deposits, produced on zinc by electrochemical displacement from their salt solutions, in 1 *N* sulphuric acid, were examined by X-rays. All were found to contain re-deposited zinc; the copper coatings showed approximately 9-13 at. per cent. in solid solution, the nickel deposits 17-20 at. per cent. In the gold deposits very large amounts of zinc were present, but the silver deposits contained less than 0·5 at. per cent. zinc. In all cases the grain size was very small, due to inhibition of growth by co-deposited zinc.

During the displacement of silver, zinc deposited mostly as a very thin layer, on the surface of the grains, whereas the other three metals absorbed zinc readily, forming α phases. Displacement is brought about by the activity of local cells; zinc acts as the anode and the nobler metal forms very small cathodes. The re-deposition of zinc on these cathodes is possible because it is deposited in the form of a solid solution, the free energy of which is reduced.

NON-FERROUS ALLOYS

Properties and Applications of Cast Monel

N. S. MOTT: 'Uses Broaden for Cast Monel.' *Iron Age*, 1951, vol. 167, Jan. 11, pp. 63-7.

Cast Monel, increasingly used for shapes which are difficult or expensive to fabricate, is produced in three types, typical compositions of which are shown in the table below.

Typical mechanical and physical properties of the alloys are given in the paper.

The following conditions are noted as desirable in production of cast Monel: Melting should be done in an acid arc furnace, and for protection a glass slag is preferred. When scrap is being melted, calcium may be added, if necessary, to quiet the bath. Pouring temperatures are 2550°-2600°F. (1400°-1425°C.) for large castings; 2750°-2800°F. (1510°-1540°C.) for small ones, where running is more difficult. To prevent embrittlement by sulphur, 1 oz. magnesium is added per 100 lb. of metal, the addition being made in the ladle before pouring. The effect of sulphur, and the action of magnesium in inhibiting its deleterious influence, are discussed. The nature of the cored or dendritic structure formed in cast Monel on solidification is illustrated by photomicrographs.

One of the outstanding characteristics of Monel is its resistance to corrosion under reducing conditions; it is therefore suitable for some applications in which the stainless steels are not so resistant to attack. Monel is immune from stress-corrosion cracking in hydrochloric acid or in chloride solutions, and also from embrittlement in strong caustic solutions.

The usefulness of Monel in contact with acids under reducing conditions is an important feature; sulphuric acid may be handled in concentrations of less than 80 per cent., at most temperatures, and hydrochloric acid in concentrations up to 20 per cent. at temperatures up to 160°F. (70°C.). Introduction of air or oxygen markedly accelerates corrosion, as does the presence, in the acids, of oxidizing salts, particularly those of iron and copper.

Monel has also very useful resistance to hydrofluoric acid, to neutral and alkaline salts, and to acid salts if they are non-oxidizing and the solutions are free from air. It is highly resistant to solutions of caustic alkalis, at quite high concentrations and temperatures, but above 55 per cent. concentration nickel is to be preferred to Monel, and at 75 per cent. Monel corrodes too rapidly to be useful.

Monel also shows good resistance to anhydrous halogens and halogen acids. It resists the action of fluorine and hydrogen fluoride up to 1000°F. (540°C.), chlorine up to 800°F. (425°C.) and hydrogen chloride up to 450°F. (230°C.). In the absence of sulphur Monel resists attack in an oxidizing atmosphere up to 2000°F. (1095°C.), and in a carbon monoxide reducing atmosphere it gives good service up to 1500°F. (815°C.). When sulphur is present the temperature limit is 600°F. (315°C.) under oxidizing, and 500°F. (260°C.) under reducing, conditions. A table in the paper gives qualitative data on resistance of cast Monel to a wide range of corrosives.

A further important use of cast Monel, particularly of the high-silicon grades, is as a non-galling, wear- and erosion-resisting material.

Cast Monel of the regular type may readily be welded,

Chemical Composition

Type	Ni %	Cu %	Fe %	Mn %	Si %	C %	S %
Monel ..	63	32	1·5	0·75	1·5	0·15	0·015
Monel 'H' ..	63	31	2	0·75	3	0·10	0·015
Monel 'S' ..	63	30	2	0·75	4	0·10	0·015

by either arc or oxy-acetylene methods; in the latter case a reducing flame should be used, and, for complicated castings, a pre-heat of 200°-300°F. (95°-150°C.) is advisable. Welding of the 'S' and 'H' grades is not recommended, due to tendency toward cracking: only mechanical joints should be used with these alloys.

Machinability of regular Monel castings is good, that of 'H' Monel is fair, and 'S' Monel requires prior annealing at 1650°F. (900°C.), followed by air cooling. After annealing, 'S' Monel castings must be re-hardened by heating at 1100°F. (595°C.) for 4 hours, followed by furnace cooling to 600°F. (315°C.), from which point they are air cooled. This treatment produces a Brinell hardness of 300-400.

Nickel in Brass and Bronze Alloys

J. S. VANICK: 'Bearing Metals: 'Nickel-Alloyed Brass and Bronze.' *Foundry*, 1950, vol. 78, Dec., pp. 80-3, 211-12.

The article is the third of a series dealing with the effects of low and medium percentages of nickel in brass and bronze alloys of various types. For reference to Parts I and II see *Nickel Bulletin*, 1950, vol. 23, Nos. 10 and 12, pp. 181 and 225: see also next abstract for reference to reprint.

A review is made of the compositions and properties of copper-nickel-tin-lead and nickel-antimony bearing bronzes, and of babbitt and other 'special' bearing materials in which the presence of nickel confers appreciable improvement in service behaviour. Tabular data are included on typical mechanical properties of the various grades, and the influence of nickel on wear-resistance is graphically illustrated. The particular applications for which the respective materials are specially suitable are discussed.

A reprint of the article, issued by International Nickel Co., Inc., will shortly be available.

J. S. VANICK: (1) 'Nickel-Alloyed Brass and Bronze Castings.' (2) 'Pressure Castings: Nickel-Alloyed Red Brass.'

Reprints of articles from *Foundry*, Aug. and Oct., 1950.

Sigma Phase in Nickel-Vanadium Alloys

W. B. PEARSON, J. W. CHRISTIAN and W. HUME-ROTHERY: 'New Sigma-Phases in Binary Alloys of the Transition Elements of the First Long Period.' *Nature*, 1951, vol. 167, Jan. 20, p. 110.

Brief note on work in the Inorganic Chemistry Laboratory of the University of Oxford, which has led to the discovery of four new sigma phases, the compositions of which are considered to be of interest. The alloys concerned occur, respectively, in the chromium-manganese, vanadium-manganese, vanadium-cobalt, and vanadium-nickel series. In the vanadium-nickel system an alloy containing 55 at. per cent. of vanadium has the sigma-phase structure, extending from about 55 to more than 65 at. per cent. vanadium. The authors are of the opinion that it is probably stable up to the solidus.

Results recorded in the note show that the formation of sigma phases is not connected with an equiatomic superlattice; they support the suggestion of SULLY and HEAL (*Research*, 1948, vol. 1, p. 288) that these phases are electron compounds. It has not been found possible to obtain a sigma phase in vanadium-chromium alloys, and the results are therefore taken to indicate that in alloys of the First Long Period sigma phases are found only in alloys of vanadium with elements from manganese to nickel, and in alloys of chromium with elements from manganese to cobalt. (Attention is directed to work by PIETROKOWSKY and DUWEZ, confirming the existence of the sigma phase in vanadium-nickel and vanadium-cobalt alloys: *Trans. Amer. Inst. Min. Met. Eng.*, 1950, vol. 188, p. 1283.)

Colouring of Metals and Alloys

See abstract on p. 49.

Time-Temperature-Transformation Data: Reference Bibliography

See abstract on p. 48.

Maintenance of Clad Materials

See abstract on p. 65.

CAST IRON

Commercial Production of Ductile Cast Iron

N. CROFT: 'Producing Ductile Cast Iron. Some Foundry Experiences.' *Iron and Steel*, 1951, vol. 24, Feb., pp. 45-50.

This article records the experiences of a British firm manufacturing magnesium-treated cast iron under Mond licence. A variety of castings has already been produced for extensive field tests; many of these have proved satisfactory in service and are now in bulk production. In other cases, in which longer trials are required to prove the utility of the new material, interim reports indicate that results are likely to be equally satisfactory.

For a review of information available on the spheroidal-graphite cast irons, reference is directed to the paper presented by A. B. EVEREST at the 1950 meeting of the Institute of British Foundrymen (for abstract see *Nickel Bulletin*, 1950, vol. 23, No. 7, p. 130).

The record of experience in the foundry of Lloyds (Burton), Ltd., with which the present author is associated, opens with a diagram demonstrating the consistency of mechanical properties which can be obtained in spheroidal-graphite cast iron produced under the correctly controlled conditions maintained by this and other licensed foundries. Experience in

exploratory and proving tests has indicated that the following minimum specification can consistently be met under commercial conditions.

As-cast: U.T.S. 35 tons per sq. in.

Annealed: U.T.S. 30 tons per sq. in.; Elong. 10 per cent.

The following proved to be a suitable composition for the basis iron: total carbon 3·0-3·5, silicon 1·9-2·0, sulphur 0·10 max., manganese 0·4-0·5, phosphorus 0·05-0·2, per cent. Within the range shown, the manganese and phosphorus contents are preferably kept to the lower levels. When maximum resistance to impact is imperative, final silicon should be relatively low, and it is emphasized that, for the development of the best properties attainable, phosphorus must be kept down. For maximum economy the sulphur content of the basis iron should be at a minimum, although it is possible to treat, with complete success, cupola-melted iron having a sulphur content in the range 0·08-0·12 per cent. The greater part of the iron treated in the author's foundry has contained sulphur of the order of 0·10 per cent.

Methods of addition of magnesium-bearing alloys to cast iron, precautions required, and effects produced, are outlined, with illustrations. Normal sand practice has been found suitable for moulding and core making, but methods of gating and feeding require modification from those used for ordinary cast iron, due to the differences in solid and liquid contraction. Suitable procedure is described and illustrated. Tests in the author's foundry have shown that patternmaker's contraction allowance should be about $\frac{1}{12}$ in. per foot. Liquid shrinkage in magnesium-treated cast iron is somewhat similar to that occurring in steel; methods of feeding usual with cast iron therefore require modification in the direction of those used in the steel foundry. Fluidity of ductile cast iron is, in spite of the somewhat lower casting temperature resulting from loss of heat during alloy addition, almost equal to that of the base iron. Modification of gating procedure, designed to eliminate susceptibility to pin-holing, is described.

A factor of importance in successful production of magnesium-treated iron is maintenance of cleanliness of the iron at all stages. Use of the 'tea-pot' form of ladle is recommended, and it is also desirable that the gating system should include slag traps, to hold back any non-metallic matter left after skimming. It is found preferable to allow the castings to cool in the mould as long as possible, after which heads and runners are removed by notching and breaking, or by oxy-acetylene cutting. Castings to be supplied in the as-cast condition are given a stress-relief treatment at 500°C.; one hour+one hour for each inch of section. Where maximum ductility is required castings are heated at 850°C. for one to three hours (depending on the section) and are then slowly cooled, over a period of two to three hours, to a point just below the recalescence temperature, and held there for five to eight hours, depending on the type of casting being treated.

Typical castings, illustrating the wide range to which the magnesium treatment is applicable, are shown in the paper.

In order to ensure the close control of magnesium content essential for successful production, analyses on each cast are made in the Lloyd foundry; the method used is briefly described.

Experience to date may be summarized by saying that the new cast irons can be made consistently and satisfactorily, and that the material is already commercially available on a scale of practical interest to the designer and the engineer. Much work still remains to be done before the vast field opened by ductile cast iron is fully explored.

Bibliography on Nodular-Graphite Cast Iron

F. R. MORRAL: 'Nodular Iron; A Bibliography.' *Amer. Foundryman*, 1951, vol. 19, Jan., pp. 43-4.

The *bibliography* is supplementary to that published *ibid.*, 1950, vol. 18, July, pp. 61-64.

It lists publications which have appeared since the date of compilation of the earlier one, and contains a classified index to items in both sections of the bibliography.

Damping Capacity and Elastic Modulus of Cast Iron as Influenced by Structure

R. CABARAT, L. GUILLET and C. PRUDHOMME: 'Influence of Form of Graphite on Internal Friction in Cast Iron.' *Rev. de Métallurgie*, 1951, vol. 48, Jan. pp. 47-9; disc, p. 49.

The authors present results of tests on nodular- and lamellar-graphite cast irons in various conditions, and on typical plain and alloy white irons. The results confirm earlier data, in indicating that graphite lamellae act as notches, setting up, in their immediate vicinity, a condition of restraint much greater than that operating throughout the mass of the iron. Decrement values for the ordinary (lamellar) cast irons studied were of the order of $20\text{-}30 \times 10^{-4}$ and their elastic moduli were within the range 13,000-14,700 kg/mm². For the spheroidal-graphite cast irons decrement value was in the region of 5×10^{-4}, and the elastic modulus was about 18,000 kg./mm², i.e., of the same order as that of steel.

Alloy Cast Irons: Review of Developments in Structure and Properties

C. VAN DER BEN: 'High-Duty Cast Irons.' *Alloy Metals Rev.*, 1950, vol. 8, Dec., pp. 2-8.

The author reviews, with many photomicrographic illustrations, the history of the use of special alloy additions in cast iron. The basic character and structure of cast iron is discussed, and the modifications introduced in structure and properties by inoculation, and by the addition of nickel, copper, chromium, vanadium and molybdenum, are considered. The properties of irons modified by such additions are discussed, with particular reference to types of outstanding interest, e.g., acicular- and nodular-graphite irons.

Manufacture of Nickel-Alloy Cast Iron Chilled Rolls

K. H. WRIGHT: 'Chilled-Roll Manufacture.' *Foundry Trade Jnl.*, 1951, vol. 90, Jan. 11 and 18, pp. 33-40; 61-7; disc., pp. 76-8.

This practical and comprehensive paper is presented in two sections. In the first part the author discusses the history of roll development (with references to the literature), and also reviews the characteristics essential in chilled cast-iron rolls, dealing with the intrinsic nature of the product, control of chilling, compositions suitable for this application, and stability of structure. A chart shows the range of rolls now manufactured, and detailed consideration is given to the special types of roll produced for various applications in modern industry. The value of controlled alloy additions is emphasized, and structures of rolls in which nickel, chromium, molybdenum and other additions are utilized are illustrated. The variety of properties which may be obtained, and the grading of structures to ensure the requisite characteristics, are discussed in detail. Among the aspects of the subject to which considerable attention is given are duplex rolls, and indefinite-chill rolls.

Part 2 of the paper deals with production methods, covering moulding set-up, the surface treatment of chills, melting of the roll metal, furnaces suitable for this work, composition of charge, melting conditions, etc. Finally, some account is given of testing and inspection methods, with particular reference to hardness testing of the finished rolls.

CONSTRUCTIONAL STEELS

Time-Temperature-Transformation Data: Reference Bibliography

See abstract on p. 48.

Fatigue Properties of Nickel-Alloy Steels

T. T. OBERG and W. J. TRAPP: 'High-Stress Fatigue of Alloy Steels.' *Product Engineering*, 1951, vol. 22, Jan., pp. 159, 161, 163.

Most published information on fatigue properties of metallic materials relates to the region of the endurance limit. While such stress data are important in relation to design of parts which will be subjected to alternating loads for indefinite periods, many designs may be subjected to a relatively small number of load cycles, and the use of the endurance limit in such applications results in an 'over-designed' part. In order to avoid this condition it is desirable to apply fatigue data in the yield-point region of the material: there is, however, a lamentably small amount of information at such high stress levels.

The present authors show graphs relating to tests on three aircraft steels (S.A.E. 2330 nickel, and S.A.E. 4340 and 8630 nickel-chromium-molybdenum) tested by means of reversed bending and axial loading, the rate of loading being varied between 90 and 3450 cycles per minute. Applied loads were chosen to cause failure, in most of the specimens, between 5,000 and 100,000,000 cycles.

Cast Nickel-Chromium-Molybdenum Steel Rolls

S. R. ROBINSON: 'Manufacture of Cast Steel Rolls.' *Foundry*, 1950, vol. 78, Dec., pp. 188, 190, 192.

The article is a practical discussion of some of the problems involved in production of cast-steel rolls, methods for avoidance of defects, e.g., hard spots, use of chills, heat-treatment, etc. A table shows compositions of steels in current use for cast rolls of various types.

Particular reference is made to heat-treatment of nickel-alloy steel rolls which are especially suitable for use as mechanical sheet-mill breakdown rolls and as back-up rolls for cluster mills. The composition of the steel is as follows: carbon 1·40-1·50, manganese 0·90-1·10, silicon 0·25, chromium 1·05-1·10, nickel 1·25-1·50, molybdenum 0·40-0·50, per cent.

A typical annealing cycle comprises heating at 1750°F. (955°C.) over a period of 111 hours, holding at that temperature for 38 hours, cooling to 600°F. (315°C.) over a period of 38 hours, re-heating to 1450°F. (785°C.) over a period of 51 hours, and holding at that temperature for 30 hours. After cooling and machining the rolls are given a second heat treatment consisting in heating at 1550°F. (840°C.) for 18 hours, cooling in air under a fan, tempering at 925°F. (495°C.) for 12 hours, and furnace cooling.

Among the general recommendations made, as conducive to production of sound serviceable cast steel rolls, are the following:—In melting, ensure that residual silicon is reduced to 0·03-0·06 per cent., and that a vigorous boil is maintained for a sufficient time to eliminate harmful gases. All heats containing 1 per cent. or more of carbon should be re-ladled. Correct pouring temperature is a vital factor. Eliminate chilling so far as possible; it is estimated that it adds at least 30 per cent. to the labour cost involved in making the roll mould, apart from costs associated with making, handling and storage. Refractory quality of the moulding sand used should be high, and the moulds should be thoroughly baked.

Stainless-Steel Trains

See abstract on p. 65.

Resistance of Nickel-Chromium-Molybdenum Valve Steels to Graphitization

T. N. ARMSTRONG and R. J. GREENE: 'Nickel-Chromium-Molybdenum Steel Valve Casting after 50,000 Hr. of Service at 900°F.' *Amer. Soc. Mechanical Engineers, Paper* 50-*A*-67, Nov.-Dec., 1950; 3 pp.

Long-term service at 900°F. (480°C.) and above in power stations has revealed that certain steels which had previously been considered suitable for such applications deteriorate much more rapidly than

would have been anticipated, and that the major cause of such deterioration is graphitization. An extensive literature has already grown up relating to this type of failure.

One of the materials which have proved suitable for cast valves and other fittings in steam plant operating at temperatures up to 950°F. (510°C.) is a nickel-chromium-molybdenum steel conforming to the requirements of grade WC-4 of A.S.T.M. Specification A-217: the composition is shown below.

Laboratory tests had indicated that this steel is highly resistant to graphitization under small-scale experimental conditions (*Trans. Amer. Soc. Mech. Eng.*, 1946, vol. 68, pp. 609-24; see also *Nickel Bulletin*, 1946, vol. 19, No. 9, p. 150). The present paper reports long-time service tests (six years' duration) made, in the power plant of the Detroit Edison Company, to test the validity of the conclusions drawn from the laboratory tests.

The valve examined (withdrawn while apparently still fit for indefinite further service) had been in continuous operation, at a nominal temperature of 900°F. (480°C.), at an average pressure of 841 p.s.i.

Chemical analysis of the valve casting is shown in Table I, together with the present A.S.T.M. specification for this type of steel. At the time the casting was made this specification was not in effect, but it will be noted that the composition of the specimen conforms very closely to the current requirements, with the exception of rather lower molybdenum content. The castings had been subjected to the following heat-treatment: 5 hours at 1800°F. (980°C.), furnace cooled; re-heated for 5 hours at 1550°F. (840°C.) air cooled; re-heated at 1200°F. (650°C.) for 5 hours, air cooled.

Stellite-faced seat rings and pipe ends had been welded to the body by metal-arc process.

Results of tensile tests on coupons heat-treated with the casting are shown in Table II, in comparison with the values obtained on specimens cut from the valve after it had been withdrawn from service. The following comments are made:—

'Strength values of specimens cut from the casting are in close agreement with those of the test coupon, and, although the ductility of the casting specimens is somewhat lower, this is to be expected (see *Steel Castings Handbook*, 1941, p. 143). The impact properties of the casting specimens are slightly lower, with one exception, than the values for the test coupon, but there is no indication of brittleness. The one high value for the casting is probably due to a preferred microstructure resulting from rapid cooling from high temperature during welding. As impact values in the heat-affected zone usually fall within a wider scatter band than test values in unwelded areas, these results follow the general pattern.'

Examination of eight randomly selected welded areas of the casting, including specimens from areas likely to be most susceptible to deterioration, showed no indication of graphite formation, nor was there any evidence of concentration of carbides which might indicate a stage preliminary to graphitization.

The results of the examination are therefore throughout in agreement in showing that there was no loss

Table I

Chemical Composition

	C %	Mn %	Si %	P %	S %	Ni %	Cr %	Mo %
Valve Casting ..	0·21	0·62	0·39	0·030	0·017	0·99	0·61	0·37
Specification Limits	0·20 max.	0·50-0·80	0·60 max.	0·050 max.	0·060 max.	0·70-1·10	0·50-0·80	0·45-0·65

Table II

Tensile and Impact Tests

Location	Yield Strength		Tensile Strength		Elongation % in 2 in.	Reduction of Area %	Charpy Impact V-Notch ft.-lb.	Brinell Hardness
	p.s.i.	t.s.i.	p.s.i.	t.s.i.				
Test coupon* ..	54000	24·1	84700	37·8	26·2	52·2	32	170
Casting	57400	25·6	82200	36·7	20·5	30·3	22	166
Casting	54100	24·1	82100	36·6	22·0	45·5	21	163
Casting	53400	23·85	83400	37·25	16·5	26·5	24	166
Heat-affected zone	—	—	—	—	—	—	24	207-240
Heat-affected zone	—	—	—	—	—	—	43	200-255
Specifications ..	40000	17·85	70000	31·25	20·0	35·0	—	—

* These values reported by the valve manufacturer.

of strength, no embrittlement and no occurrence of graphite in the welded casting after the six-year service period.

Materials of Construction for Chemical Plant

See abstract on p. 61.

B.S. Specifications for Steels for Chemical Plant

See abstract on p. 60.

B.S. Specifications for Pipes and Tubes for Pressure Vessels

See abstract on p. 60.

Nickel-Alloy Steels for Die Blocks

H. J. MERCHANT: 'Die-Block Steels for Drop Forging; Composition and Treatment.' *Metal Treatment and Drop Forging*, 1951, vol. 18, Jan., pp. 13-21, 24.

The author discusses various aspects of the technology and economics of die-block selection and use. Primary requirements for die-blocks are considered to be:—
(1) soundness and freedom from internal defects; (2) correct heat-treatment, to give the best combination of hardness and toughness for the work required; (3) uniformity of heat treatment, to ensure machinability, and absence of residual stresses, (4) suitability of steel composition, quality and grain size, to provide maximum depth-hardening capacity and minimum distortion; (5) resistance to deformation and wear by abrasion; (6) high resistance to impact; (7) optimum arrangement of grain flow relative to the type of work and die layout; (8) correct matching in hardness of the dovetailed blocks to those of the hammer tups or sowblocks in which they will be tooled; and (9) resistance to deterioration at the elevated temperatures involved in working, and to heat-checking.

Compositions of steels for die blocks and of some steels in common use are tabulated.

The author discusses, from an essentially practical standpoint, the factors influencing selection of the respective grades for individual types of work; the effects of the alloying elements present, as contributing to the properties required; hardness ranges preferred for die-block service; specification and testing; heat-treatment and maintenance.

HEAT- AND CORROSION-RESISTING ALLOYS

Nickel-Alloy (N-155) Cast Turbine Rotors: Production and Properties

N. J. GRANT, L. W. KATES and N. E. HAMILTON: 'Development and Evaluation of Cast Turbine Rotors.' *Foundry*, 1950, vol. 78, Dec., pp. 86-93, 234-9.

This paper contains a highly detailed description of experiments conducted at the Massachusetts Institute of Technology, under contract for the U.S. Bureau of Ships. The research covered investigation of the conditions requisite for production, in alloy N-155, of the structure and properties ensuring optimum behaviour under conditions of stress and temperature involved in gas-turbine rotor service. The nominal composition of the alloy studied is given as nickel 30, chromium 20, cobalt 20, molybdenum 3, tungsten 2·2, niobium 1·3, manganese 1·5, carbon 0·15-0·30, per cent.

Preliminary study of a series of ingot castings established:— the importance of close control of carbon content, in order to ensure minimum specified room-temperature tensile properties and stress-rupture values at 1500°F. (815°C.): influence of pouring temperature on structure: relatively slight significance of mould-preheat temperature: necessity for solution-treatment and ageing, in order to obtain optimum mechanical properties.

On the basis of these tests, a second series of ingots was cast, in production of which conditions were selected to provide the following series of structures: (1) fine-grain equi-axed, (2) coarse-grain equi-axed, (3) columnar, (4) columnar (low-carbon alloy).

On these specimens the authors determined the influence of heat-treatments, as affecting rupture life, hot ductility, and room-temperature mechanical properties and ductility.

After consideration of the results of these tests a series of cast rotors was prepared, embodying the structures considered likely to give satisfactory properties under service conditions. Production conditions used in investment casting and casting in graphite moulds are described in close detail. Some 50 rotors were cast, typical examples of which are illustrated in the paper, relating structural formation to casting conditions. In general, test bars machined from the cast rotors showed the same trend in stress-rupture properties relative to structure as had been observed in the experimental ingots, but some unexpected discrepancies are reported.

In addition to conclusions deduced from individual series of tests, general comments are made on certain broad conclusions to be drawn from the investigation as a whole. Some of the outstanding points are noted below.

An all-columnar structure proved to be the most desirable, from the point of view of hot and cold strength and ductility. It was found difficult, with the equipment available, to obtain this structure in the rotors, particularly in thin sections, but it is considered that a full-size foundry, having means for transporting the molten metal rapidly from furnace to mould could pour castings within the required range (about 1550°C. and not lower than 1525°C.), and thus consistently obtain the required columnar structure without difficulty.

The problem of obtaining a satisfactory surface on a casting poured in a graphite mould was not solved; none of the castings made had a usable as-cast surface. It is therefore suggested that castings of this type be made oversize, and machined to final dimensions. It is considered that the upper limit of regular investment castings appears at present to be about

100 pounds, and that a better refractory combination must be developed before this limitation can be overcome. The suitability of the coarse equi-axed grain structures which would be obtained when using refractory moulds, for service application, would require to be established by hot-spin or service tests.

It is recommended that N-155 rotors be solution treated regardless of structure. Two hours at 2200°F. (1200°C.), followed by air-cooling and ageing at 1350°F. (732°C.) for about 24 hours gives high room-temperature tensile properties and good stress-rupture characteristics at 1500°F. (815°C.).

Rotors cast in investment moulds exhibited properties generally inferior to those of rotors cast in graphite, but the authors developed certain modifications in investment-casting technique which gave considerable improvement in quality. Particular attention is called to the advantage of decreasing the size of the hot-top riser, and adding 1-2 kg. of a commercial thermite mixture (Risotherm) in the hot top after pouring the heat.

Tests with alloys of varying carbon content (0·085-0·30 per cent.) indicated that increase in strength may be anticipated with rise in carbon up to 0·30 per cent., but it is probable that if the carbon content were too high ductility would decrease, leading to embrittlement, particularly at room temperature.

As an indication of the potential value of cast rotors, a tabular comparison is made of the properties of a low-carbon forged N-155 disc, and those of cast N-155, (*a*) in the fine-grained equi-axed condition and (*b*) in the columnar-grain condition.

The authors plan to carry out hot-spin tests on rotors of controlled structure made by the methods described.

High-Temperature Properties of Austenitic Nickel-Chromium Steels containing Silicon

E. E. REYNOLDS, J. W. FREEMAN and A. E. WHITE: 'Investigation of Properties of A.I.S.I. Type 310 B Alloy Sheet at High Temperatures.' *Nat. Advisory Committee for Aeronautics, Tech. Note* 2162, Aug., 1950; 37 pp.

The steel containing chromium 25, nickel 20, silicon 2, per cent., is known to have oxidation-resistance and strength properties which render it suitable for use as sheet material for gas-turbine parts. It is, however, subject to development of low ductility in the range 1200°-1400°F. (648°-760°C.), as the result of precipitation and, probably, formation of the sigma phase.

The investigation reported was undertaken to determine whether service at 1700°-1800°F. (926°-980°C.), particularly in the combustion chambers of jet engines, would cause increased brittleness in the 1200°-1400°F. range, with resultant difficulties during heating and cooling. Experiments were also carried out to ascertain the influence of even higher temperatures, on the characteristics within the sensitive range. A supplementary section of the study comprised tests to determine (*a*) the effect of heat-to-heat variations, and (*b*) the influence of prior treatment on the tensile properties of the steel over the range 900°-2000°F. (482°-1093°C.), and on the rupture properties at 1700° and 1800°F. Results of the individual series of tests are fully reported.

The following major conclusions are drawn from the data presented:—

Minimum ductility observed in tensile tests at 1300°F. (704°C.) would be substantially increased by heating at 1700°-2000°F. (926°-1093°C.) for short periods. Prolonged exposure (5 hours) at 1700° and 1800°F. would not, however, be expected to cause low ductility at 1300°F. in annealed sheet.

The low ductility at about 1300°F. is believed to be the result of the type of precipitation occurring in that range (probably 'some form of sigma phase'.* Heating at 1700°-1800°F. results in prior precipitation and agglomeration of excess constituents which apparently reduce the embrittling precipitation process at 1300°F.

Up to 1800°F. hot-rolled and cold-rolled sheet showed substantially higher tensile strength than annealed sheet. The ductility of the cold-rolled sheet was, in general, the lowest. A 0·16 per cent. carbon heat showed higher rupture strength at 1700° and 1800°F. than two 0·05 per cent. carbon specimens.

Influence of prior treatment on rupture properties proved less than had been expected, but this conclusion is given with reservation, since a very low effective carbon content may have influenced the results, due to contamination of the 0·05 per cent. carbon stock with titanium. Wide variation in grain size between the different heats did not influence properties.

**The authors report that in some of their samples the etching characteristics of the specimens were not characteristic of the sigma phase, but that on the evidence of other investigators they believe that the conditions to which the specimens had been subjected would give rise to sigma formation.*

History of Corrosion Research

W. LYNES: 'Some Historical Developments Relating to Corrosion.' *Jnl. Electrochemical Soc.*, 1951, vol. 98, Jan., pp. 3c-10c.

The author has attempted to make a chronological survey of some major developments in corrosion research, giving references to papers and patents which are considered to form significant contributions to the advancement of understanding of the nature of corrosion, or the control of its manifestations.

After a brief note on the initial history of the subject, a review is made of early developments in the electrochemical concept of corrosion. This is followed by a list of significant literature, classified in sections covering: (1) principles, (2) corrosion-resistant alloys, (3) protective coatings, and (4) protective treatments. The list is obviously of a highly selective nature, and is published with the proviso that many other contributions to development could well have been included. The *bibliography* terminates at 1939.

An appendix contains excerpts from a few of the earlier papers.

Corrosion of Stainless Steel by Water containing Hydrogen Sulphide

J. E. TRUMAN: 'Tensile Failure of Carbon and Stainless Steel Wires in the Presence of Water and Hydrogen Sulphide.' *Metallurgia*, 1951, vol. 43, Jan., pp. 8-10.

Following a condensed review of earlier literature, a report is made of tests in which the behaviour of

wires of the following materials was determined, under stress, in contact with water containing hydrogen sulphide: bright carbon steel (90/100-ton tensile type); 13 per cent. chromium steel; 18-8 chromium-nickel, 18-8-Ti and 18-8-Mo steels.

Portions of the wires were enclosed in a glass tube, using rubber bungs to close the ends: holes made for the passage of the wire were filled with paraffin wax to form a seal. Each tube was half filled with tap water and the wires were stressed by hanging appropriate weights to a protruding end of the wire. One sample of each wire was tested in this way without addition of hydrogen sulphide, keeping the load on continuously, in order to accelerate the action. A second series of tests was made with hydrogen sulphide slowly bubbling through the water for 8 hours daily, stopping the flow and taking off the stress daily and at week ends between the 8-hour periods. All tests were made at room temperature.

Tests results are tabulated. The observations made show that the combination of tap water and hydrogen sulphide can produce very considerable reduction in the life of steel specimens stressed to 40 per cent. of their maximum stress. Under conditions in which the stress was operating during a quarter of the exposure time, presence of hydrogen sulphide caused reduction, in the carbon steel to 8 per cent. of the life without such addition and in the chromium steel to 30 per cent. of the corresponding value. Austenitic 18-8 chromium-nickel and 18-8-Ti steel gave 'hydrogen-sulphide lives' of 1,000-2,000 hours, but specimens of these steels exposed in the non-contaminated tap water remained unbroken under continuous stress for over 6,000 hours. The indications were that the presence of the hydrogen sulphide produced more corrosion and a considerable loss of ductility, but in no case were the branched cracks, normally associated with stress corrosion, observed. The actual penetration and extent of attack did not appear to be very great in the case of 18-8 and 18-8-Ti steels. 18-8-Mo steel proved superior to all the others tested, suffering no visible attack and showing no signs of fracturing up to 10,800 hours.

Spinning of Nickel-Chromium Steel Cream-Separator Bowls

L. W. COURT: 'Power Spinning Eliminates Annealing and Descaling.' *Machinist*, 1951, vol. 95, Jan. 20, pp. 90-1.

This brief article describes, with informative diagrams, the power-spinning procedure standardized in the plant of International Harvester Company for production of bowl shells for cream separators. Introduction of power spinning, using a specially designed form of hydraulic machine, has made it possible to eliminate annealing and subsequent descaling operations previously required. Four press operations have been dispensed with, and high-cost polishing operations have been minimized. Type 302 cold-rolled stainless steel of drawing quality is used. The sequence of operations is described and well illustrated.

Machining, Shearing and Pressing of High-Alloy Steels

J. A. MCWILLIAM: 'Manipulation of Corrosion- and Heat-Resisting Steels.' *Welding and Metal Fabrication*, 1951, vol. 19, Jan., pp. 19-24.

A condensed manual of recommended practice for machining, shearing and pressing of commonly used grades of corrosion- and heat-resisting steels of the martensitic and austenitic types. Diagrams and tables contain useful information on tool set-up, arrangement of work, speeds and feeds, etc., and precautions to be adopted in carrying out the various operations. In the section on pressing, the sequence of operations involved in deep-pressing of a container of 18-8-Mo steel of the Firth-Vickers F.M.B. type is described in some detail.

B.S. Specifications for Steels for Chemical Plant

'Steels for Use in the Chemical, Petroleum and Allied Industries.' *B.S.* 1501-1506: 1950. 66 pp. Price 12/6.

This series has been issued as part of a comprehensive scheme of codes for pressure vessels for use in the chemical and allied engineering industries. It covers plates, bars and sections, forgings, castings, and bars for bolting material. [B.S. 1500 'Code for Fusion Welded Pressure Vessels for Use in the Chemical and Allied Industries' gives recommended stress values for the steels included in the 1501-1506 standard when used in construction of pressure vessels, and indicates the temperature ranges within which they may safely be used.]

The 1501-1506 schedules cover (in some or all of the sections) carbon steels of various carbon contents, and alloy steels of the following types: carbon-manganese, carbon-molybdenum, chromium-molybdenum, high-chromium, and austenitic chromium-nickel and chromium-nickel-molybdenum.

Appendices give particulars of—

(1) British Standard forms of test piece (tensile and notched-bar).
(2) Method of numbering British Standards for steels for use in the chemical, petroleum and allied industries.
(3) Comparable British and American (A.S.T.M. and A.I.S.I.) specifications.

B.S. Specifications for Pipes and Tubes for Pressure Vessels

'Steel Pipes and Tubes for Pressure Vessels for Use in the Chemical and Allied Industries.' *B.S.* 1507/1508: 1950. 38 pp. Price 10/6.

These specifications are additions to the series referred to above.

No. 1507 covers seamless and lapwelded pipes of mild steel, and seamless pipes of carbon-molybdenum, chromium-molybdenum and austenitic chromium-nickel and chromium-nickel-molybdenum steels.

No. 1508 covers seamless tubing of mild steel, and low-molybdenum, chromium-molybdenum and austenitic chromium-nickel and chromium-nickel-molybdenum steels.

Appendices include details of the numbering system which has been adopted by British Standards Institution for steels for use in the chemical and allied industries, and a table in 1507 shows comparable British and U.S. standard steels.

Materials of Construction for Chemical Plant

J. A. LEE: 'Materials of Construction for Chemical Process Industries.' *Published by McGraw-Hill Book Co., Inc.*, New York, Toronto, London, 1950; 468 pp. Price £2 15s. 6d.

The author describes this book as 'written to bring together and correlate the information he himself often needed and found only with the greatest difficulty'. It comprises a review of materials of construction which have been found, by operating experience, to be the most serviceable and economical in commercial-size plants.

The information is presented in sections covering individual chemicals and combinations of chemicals: more than 300 are included. The uniform plan of the sections, where full information is available, is (1) a summary of the essential features of the processes involved in production of the chemical(s), and in handling and packaging; (2) notes on metallic and non-metallic materials of construction used; (3) discussion of the corrosive characteristics of the chemical when used as a finished product, or as a raw or intermediate material in the production of some other chemical or product.

Much of the information has been culled from published sources, notably *Chemical Engineering* and its predecessor, *Chemical and Metallurgical Engineering*. This has been supplemented by hitherto unpublished data, based on the author's own experience or specially contributed to him by other chemical engineers.

As far as has been found practicable, trade names of materials have been avoided; where such use has been inevitable, chemical compositions are given in a table at the end of the book.

The compilation forms a practically useful reference manual presented in a form which facilitates quick access.

Nickel-containing Materials in Pulp and Paper Processing

H. O. TEEPLE: 'The Use of Nickel-containing Alloys in the Pulp and Paper Industry.' *Paper Trade Jnl.*, 1950, vol. 131, No. 9, pp. 28, 30-2; Nov. 16, pp. 19-23; Nov. 23, pp. 14-15, 18-19, 21-5.

Reprint issued by International Nickel Co., Inc., 1951; 19 pp.

A very comprehensive review, indicating the many uses of nickel-containing alloys, steels and cast irons, in various stages of processing in pulping and paper making and finishing. The materials considered include nickel and the high-nickel alloys (Monel, Inconel, the Hastelloys); austenitic stainless steels, e.g., of the S.A.E. 304 and 316 types, high-alloy cast irons such as Ni-Resist, and corrosion-resisting clad materials.

The author opens with a succinct review of earlier major literature, and subsequently deals, in detail, with the uses of the respective materials. Sections of Parts I and II of the paper discuss specifically the following aspects of the subject, presenting a mass of information based on service experience and supported by references to the literature:—

Alkaline pulping, sulphate pulping, acid pulping; handling of calcium-base, magnesium-base, ammonium-base, and sodium-base liquors; groundwood pulping; equipment used in by-product recovery.

In Part III, covering paper making, the discussion follows the line of flow of stock from the digester to the paper machine, dealing with equipment used in pulp washing, screening and thickening, material for rolls, etc. In addition, uses of nickel-containing materials in paper-board-manufacturing and in bleaching operations are covered.

Much factual information is given, and in many cases the comparison of the behaviour of nickel-containing materials with that of other types, under given conditions, considerably widens the scope of the review. The paper is well illustrated, and is supported by a *bibliography* of 80 references.

'Construction Materials in the Paper Industry. IV. Alkaline Pulping.' *Chemical Engineering*, 1951, vol. 58, Jan., pp. 217-18, 220-2, 224-6.

For summaries of earlier parts see *Nickel Bulletin*, 1950, vol. 23, No. 11, p. 218; 1951, vol. 24, Nos. 1 and 2, pp. 24 and 46.

In this section the uses of the following materials are considered: Worthite, carbon, cements, Durimet 20, high-silicon irons, Chlorimet alloys, iron and steel, rubber, nickel and nickel alloys.

Worthite is one of the materials showing practically perfect resistance to the corrosive action of the sulphate digester liquors. It is also highly resistant to the corrosive-erosive conditions existing in the handling of the black liquor-salt cake slurries for the furnace feed, and the various abrasive slurries encountered in the re-causticizing plant. These characteristics have led to its wide use in pumps and other parts in various sections of alkaline pulping plant; some typical uses are detailed.

Durimet 20 is not so extensively used in the alkaline pulping processes as in the acid processes described in the earlier sections of the symposium, since the conditions imposed do not, in many cases, call for so expensive a material. In certain positions, however, where conditions are unusually severe, Durimet has proved economically acceptable, e.g., in pumps for handling lime slurry, and in valves in the black-liquor recovery plant.

Chlorimet Alloys. These alloys find practically no application in this branch of the industry, since they are economical only for very severe service in which other alloys show unsatisfactory behaviour. It is, however, recorded that for an impeller of a pump handling lime slurry Chlorimet 3 successfully replaced Durimet 20, which failed rapidly under the combined erosion and corrosion attack involved.

Nickel and Nickel Alloys. These materials are extensively used in the alkaline pulping stages of processing. For full details of their behaviour under the conditions involved, and of their many uses the reader is referred to the paper by TEEPLE: see preceding abstract.

Corrosion-Resisting Linings in Petroleum-Refinery Equipment

G. O. CARPENTER: 'Corrosion-Resistant Liners in Refinery Vessels.' *Petroleum Refiner*, 1950, vol. 29, No. 7, pp. 95-103.

The author presents a summary of information based on experience in the plant of Esso Standard at Baton Rouge, where the use of lined equipment for corrosion-resistance has been large-scale practice for many years. The materials used for linings include various grades of high-alloy nickel-chromium steel, Monel, and Inconel, and methods of lining vary according to the particular type of equipment: plug welding, strip welding of sheet metal to the vessel wall, and lining by deposition of weld metal on a metal surface are variously used. Methods employed in forming such linings, the types of equipment in which they are respectively used, their behaviour in service, and the relative advantages and limitations of each type of lining are discussed, with informative illustrations.

With regard to the liner materials employed, the following are among the points mentioned:—

18-8 chromium-nickel steel has been used primarily to combat sulphide corrosion in medium- and high-temperature service. Older liners in the plant are mostly of Type 302; those currently being installed are mainly of Type 304.

Monel liners have been extensively used in overhead equipment and in other locations where lower temperatures prevail, under conditions which promote chloride and sulphide corrosion. Such liners are installed exclusively by the lapped, strip-welded method, in cases where clad material cannot be used.

Hastelloy B has given good service in acid pump casings, as a welded-in or deposited material. Sheet of this alloy offers good possibilities as a strip-liner material in hydrochloric-acid and sulphuric-acid service.

Inconel is being used as lining, to combat both general corrosion and stress-corrosion cracking at caustic-injection points of crude-processing units. Lining with Inconel is usually accomplished by means of lapped and fillet-welded strips, so that the exposed welds are Inconel.

Lead liners are in large-scale use in sulphuric acid service where concentrations up to 98 per cent. are to be expected. In positions at which vibration is to be anticipated tellurium-lead is employed as liner material.

Brass-lined vessels are not used at Baton Rouge, and glass has never been extensively employed as a lining material, although its superior corrosion-resisting qualities are recognized. Cements and plastics are variously used in locations in which their properties are peculiarly suitable. Correct surface preparation is an important feature in their successful application.

Nickel-containing Materials in Salt-Refinery Plant

J. A. LEE: 'How Morton Salt Refines Salt, Fights Corrosion, Handles Solids.' *Chemical Engineering*, 1951, vol. 58, Jan., pp. 102-5.

The article describes the Morton Salt Company's refinery at Grand Saline, Texas, which is the newest plant of its kind in the U.S.A. The raw materials used are rock salt and brine. The brine is refined by both vacuum evaporator and grainer systems; flow sheets of both processes are given, with details of the cycles of operation. The final product is in various forms, block, sifted, etc., and, by means of various addition materials, a wide range of remedial salt tablets is also made.

Materials of construction for this plant have been selected after many experiments and on the basis of previous experience, with the dual aim of (1) ensuring purity and non-contamination of the products handled, and (2) avoiding corrosion losses which might form a heavy overhead charge. Monel and Type 316 stainless steel are used interchangeably for many purposes, but Monel has been found to be more suitable than the steel for pipe lines handling hot brines and slurries. Ni-Resist is used for some of the hot-brine pumps, and most bolts and nuts are of stainless steel. Individual uses of the respective materials are noted in describing the various units of the plant.

Niobium- vs. Titanium-Stabilized Nickel-Chromium Steels

J. F. TYRRELL: 'Conservation of Columbium (Niobium).' *Metal Progress*, 1950, vol. 58, July, pp. 63-8.

The author urges that in view of the strategic importance of niobium, an effort should be made to conserve supplies, and that alternatives should be sought for all applications in which another element will satisfactorily replace it.

After brief reference to the use of a tantalum+niobium as a means of alleviating the shortage, detailed consideration is given to the possibility of using a greater proportion of titanium-stabilized steel. Comparison is made of the properties of nickel-chromium steels stabilized (1) with niobium and (2) with titanium, i.e., Types 347 and 321. The information given is based on experience and tests made by Solar Aircraft Company, in production of exhaust manifolds and other components.

The following points are advanced to support the argument that, in many cases, titanium-stabilized steel can advantageously be used.

Welding Characteristics. Both materials have been welded by virtually all production methods and, on equivalent sections, comparative weldability depends essentially on the welding method employed. Conditions required for successful resistance welding, welding by the inert-gas-shielded arc process, metal-arc, and oxy-acetylene welding are reviewed.

Forming. One of the major considerations in design of aircraft components is the problem of obtaining maximum thickness of section with minimum weight. In order to meet this requirement in aircraft manifolds, it is necessary to place a limit on the amount of localized thinning permissible during the forming operations. Experience indicates that localized excessive thinning, with consequent enforced rejection, is considerably higher with niobium- than with titanium-stabilized steel, and that in deep-drawing and stamping operations Type 321 (Ti) has the advantage.

Sand Casting. For castings of stabilized stainless steel Type 347 (Nb) is always chosen, due to the almost complete loss of titanium occurring on melting. Experimental heats of titanium-stabilized steel, have, however, indicated that castings can be successfully produced if modifications in alloying practice are made to compensate the high loss of titanium. Castings of the following composition have been found to give properties comparable with those of Type 347:—carbon 0·044, manganese 1·15, phosphorus 0·014, sulphur 0·005, silicon 0·92, chromium 20·05, nickel 9·36, titanium 0·24, per cent.

Engineering Properties. In this connexion a graph is presented showing average tensile strength of coupons cut from bar stock, of 347 and 321 steels, over the range 0°-1500°F. (32°-815°C.), as reported by various investigators. The data indicate that at temperatures up to about 900°F. (482°C.) the niobium-stabilized type has a slight advantage, but that at higher temperatures values are practically identical. Comparative tests on sheet stock, up to 1000°F. (538°C.) show no significant difference in the short-time tensile properties of the two steels, suggesting that they can be used interchangeably in this range of temperature when strength is the only criterion.

Creep data, culled from a wide range of published results, show a somewhat wide scatter, but are considered to justify the conclusion that any difference between titanium- and niobium-stabilized steels in this respect is probably insignificant.

Other factors of importance in determining suitability for service in aircraft components operating at elevated temperatures are *density*, *thermal expansion*, *thermal conductivity*, and *resistance to oxidation and carburization*. In the case of the thermal expansion, there is no measurable difference between the two steels. Limited data available show that Type 321 is about 50 per cent. more resistant than Type 347 to oxidation and oxidation + carburization at 1300°F. (705°C.), and some degree of superiority is maintained at still higher temperatures. Above 1500°F. (815°C.) the mechanical strength of both steels falls rapidly, and at such temperatures applications should be only for components in which stresses are extremely low.

Analysis of typical heats of the two steels in current supply shows that substitution of the titanium- for the niobium-stabilized grade would probably effect a not inconsiderable saving in nickel (average 10·11 in the 347 as compared with 11·25 per cent. in the 321 steels), and that, in addition, a small saving in manganese would be obtained.

Summarizing the position, it is concluded that 'except for specific corrosive environments there is no significant difference in engineering properties between the two materials. In aircraft and jet-engine components operating at temperatures up to about 1500°F. (815°C.) there appears to be no difference in service behaviour. In fabrication characteristics and initial cost, there are definite advantages for Type 321'.

Following publication of the above article, *Metal Progress* invited the views of a large number of leading metallurgists and chemical engineers, in both the U.S.A. and England, on the arguments and proposals put forward by Tyrrell. Letters from 56 contributors to the discussion are given in the November, 1950, issue of *Metal Progress*, pp. 691-708, 742, 744-68 (even numbers), 774-84 (even numbers).

The discussion embodied a wide variety of views, from the technical standpoint, but all express agreement with the necessity for review of practice, in the light of current requirements for minimum use of strategic materials compatible with ensuring consistently satisfactory service behaviour.

The discussion, although originating in a paper based on experience in the aircraft field, ranged over the use of stabilized steels in all industries, particular attention being directed to the conditions obtaining in, and the requirements of, the chemical industries. A statement summarizing the highlights of the discussion appears on pp. 780, 782, 784.

Current interest in the subject of niobium vs. titanium was intensified in the interval between Tyrrell's paper and the November symposium, by the issue, in October, 1950, of N.P.A. Order M-3 prohibiting the use of ferro-niobium-bearing and ferro-tantalum-niobium-bearing steels where any substitutes can be used, and reserving all niobium-bearing steels for defence purposes.

Welding of Austenitic Steel Piping for High-Temperature Service

R. W. EMERSON and M. MORROW: 'Welding High-Temperature Austenitic Steel Piping.' *Welding Jnl.*, 1951, vol. 30, Jan., Suppl. pp. 15-33; disc., pp. 33-9.

This paper discusses problems encountered in welding piping of Type 347 steel (18-10 chromium-nickel stabilized with niobium), which is coming into increasing use to meet the requirements of high-temperature high-pressure plant in power stations. Two major difficulties associated with welding this type of material are the formation of sigma phase and the occurrence of microcracks; these form the major subject matter of the present paper, which describes results obtained on three welds made in 8⅝-in. o.d., 1-in. wall forged and bored material, one weld being made manually, the other two by the submerged-arc process. The manually deposited weld was made with a 19-9-Nb electrode, balanced to produce a small amount of ferrite in the weld; one of the submerged-arc welds was made with an unbalanced 29-9-Nb electrode, the other with a standard 19-9-Nb electrode. Testing of the welded joints was carried out in accordance with the requirements of the A.S.M.E. Boiler Construction Code; all joints were radiographed prior to mechanical testing, and in most cases individual specimens were subjected to Zyglo examination. Appearance and structure of the welds, and their properties, are recorded in detail.

The experimental work included determination of the effect of stabilizing heat-treatment on mechanical properties, and of the influence of quench-annealing on hardness. Microstructure of the welded joints was closely studied, and a highly detailed investigation was made of the mode of occurrence and effect of sigma phase, correlating the authors' observations with those of other investigators. The ferrite

content of the weld deposits was calculated on the basis of the chromium and nickel equivalents, using SCHAEFFLER'S procedure (*Metal Progress*, Nov., 1949), and was experimentally determined.

In investigating microfissuring in the submerged-arc 19-9-Nb weld deposits numerous specimens were examined, both in the as-welded condition, and after air-cooling from 1600°F. (871°C.) and after water quenching from 1950°F. (1063°C.). The data obtained (illustrated by numerous photomicrographs) are in close agreement with those of others who have studied microcracking in high-chromium-nickel steels and alloys.

The major conclusions drawn from the large amount of experimental data presented are briefly summarized below:—

The manually deposited weld proved to have adequate strength and ductility when the deposit contained 3-5 per cent. ferrite, with silicon in the range 0·50-0·60 per cent. Submerged-arc welds were satisfactory when made with a 29-9-Nb electrode; the ferrite content of a weld deposit of this type was found to be 20-25 per cent.

High silicon (1·18 per cent.), which is usually associated with hot cracks in single-phase austenitic welds, is not a deterrent in this respect if the deposit contains a substantial amount of ferrite.

Submerged-arc welds made with the 19-9-Nb electrode were found to be unsatisfactory, due to microcracking. The deposit contained only 2 per cent. ferrite, and the cracks were found in the ferrite-depleted areas. Reduction of silicon and increase in chromium content of the deposit might improve the quality.

Ferrite- and austenite-forming elements in the electrodes used for joining Type 347 piping subject to high temperatures should be balanced to ensure the least possible ferrite consistent with deposition of crack-free welds.

In austenitic welds containing ferrite the latter is readily converted to sigma on post-weld heat-treatment in the range 1250°-1600°F. (675°-870°C.), or if subjected to long-time service at 1050°-1200°F. (565°-648°C.). Time-temperature relations in formation of sigma from ferrite are recorded. In deposits high in ferrite the change to sigma was 85 per cent. complete in only 300 hours at 1100°F. (593°C.). As the brittle sigma phase forms, the hardness of the weld metal rises and ductility is drastically reduced.

Austenitic weld deposits low in ferrite (and therefore having low sigma potential) remain ductile on heating at 1100°-1600°F. (593°-870°C.). Ferrite, not sigma, is the stable phase at 1800°F. (980°C.) and above. Rate of ferrite-to-sigma change in the 1100°-1600°F. range may be slowed down by previous water-quenching of the deposit.

Austenitic weld deposits high in silicon require an extra-high percentage of ferrite in the deposit for prevention of microcracks. Microcracks found in a high-silicon low-ferrite deposit made with the 19-9 electrode, by the submerged-arc process, were found to be interdendritic, resulting from hot-short low-melting complex segregates.

The authors consider that a properly welded joint in Type 347 has adequate strength and ductility in the as-welded condition, and that no specific advantages are to be gained by a post-welding treatment at 1250°-1600°F. (675°-870°C.).

The discussion on the paper, to which contribution was made by several well-known workers in this field, contains much additional information. *Inter alia*, questions were asked as to the necessity for use of the niobium-stabilized type of steel for the application under consideration, in view of the current critical position on supply.

Welding of High-Pressure, High-Temperature Steam Piping

N. L. NAVARRE: 'Welding Procedures for High-Pressure, High-Temperature Steam Piping.' *Welding Jnl.*, 1951, vol. 30, Jan., Suppl. pp. 1-9.

The author describes work done in the Welding and Electrical Laboratory of the U.S. Naval Engineering Experiment Station, as a result of which standard welding procedures have been developed for the welding of the following steels, in the form of piping, each to itself:—

(*a*) ½% Cr–½%Mo;
(*b*) 1% Cr–½%Mo;
(*c*) 2¼% Cr–1% Mo;
(*d*) 4–6% Cr–½% Mo;
(*e*) 18%Cr–8% Ni plus Nb.

The report gives details of the experimental procedures adopted in the research, and of evaluation tests used to determine the soundness and strength of the welds produced by the methods described.

Tests of composite joints between chromium-molybdenum (2¼/1%) and 18-8 chromium-nickel steels, subjected to thermal shock, indicated that 19-9 chromium-nickel stabilized with niobium is a more suitable weld metal than 25-20 chromium-nickel. Final views and recommendations regarding such composite joints, for use under conditions in which the frequency and magnitude of thermal shock are factors of primary importance, are reserved, pending completion of further research work in the Annapolis laboratory.

Budd 'Shot-Welding' of Trailer Bodies

A. I. NUSSBAUM: 'Production of Trailer-Body Components by Resistance Welding.' *Sheet Metal Industries*, 1951, vol. 28, Feb., pp. 169-73, 182.

The article describes the sequence of forming and welding operations used in the Budd plant for construction of trailer-bodies in 18-8 chromium-nickel steel. Utilizing the work-hardening characteristics of the steel, the required strength is produced by feeding the strip through progressive cold-forming rolls, to convert it to stiff-ribbed, corrugated sections, producing, at the same time, an increase in yield strength to about 120,000 p.s.i. (53·6 tons per sq. in.) and a tensile strength of the order of 150,000 p.s.i. (67·0 tons per sq. in.). The ductility of the steel so processed is still maintained at a level at which it will safely undergo subsequent forming by compression-bending or stretch-forming.

Perfection of the 'Shotweld' process of electrical-resistance welding has made possible assembly of the trailer-body structures without the use of fusion welding. The equipment used adjusts the diameter of the shot welds to the thickness of the stock treated, producing welds of uniform strength by accurate control of current, time and electrode pressure.

Stainless-Steel Trains

'Stainless Steel Trains for New York Subways.' *Engineer*, 1950, vol. 166, Dec. 29, p. 651.

Description of trains recently introduced by the Board of Transportation of the City of New York, for service on the 'Subway'.

The car bodies are of stainless steel, with the exception of the body bolsters, which are welded sections of low-alloy high-tensile steel. The high strength/weight ratio of the stainless steel, and the use of the Budd 'Shotweld' method of fabrication have permitted much saving in weight, without sacrifice of strength or safety.

Notch-Bend Tests on Austenitic Nickel-Chromium Steels

C. A. ZAPFFE and C. O. WORDEN: 'A Notch-Bend Test.' *Welding Jnl.*, 1951, vol. 30, Jan., Suppl. pp. 47-54.

The senior author recently described a special bend test designed for quantitative measurement of the bendability of metals, on the basis of a constant-rate single-bend stressing of a round bar round a fixed radius. This test was applied with success to martensitic stainless steels, and was also used in estimating the effects of steam in heat-treating atmospheres, on the properties of the steels treated. The test as originally designed, did not, however, prove capable of fracturing austenitic steels, nor ferritic steels unless they were specially embrittled.

This later paper describes modifications which have been made in the notch, to render the test applicable to all types of steel. Experiments using the modified notch are reported. These cover tests on some mild and low-alloy steels, but concern mainly stainless steels of the martensitic, ferritic and austenitic grades, including straight nickel-chromium, free-machining, and stabilized grades of the austenitic types. Particular attention is given to the influence of heat-treatment, on the bending quality of these steels.

A comprehensive survey of commercial grades of stainless steel in the cold-drawn condition indicates that: (*a*) increasing carbon in the martensitic steels markedly decreases bendability, even when the steels are not in the hardened condition; (*b*) sulphur and selenium additions present in the free-machining grades greatly reduce bendability; (*c*) increasing chromium content in the ferritic grades also causes fall in bendability, and (*d*) important differences exist between the titanium-stabilized and the niobium-stabilized austenitic steels.

Further study of the differences mentioned in (*d*) showed that Type 321 (Ti) has an exceptionally high bend rating, whether cold-drawn, annealed or stabilized, considerably exceeding that of Type 347 (Nb) and also of most other austenitic nickel-chromium steels. Stabilizing treatment of cold-drawn steels at 875°C. improved Types 321, 347 and 310 (25-20 Cr-Ni), but not Type 301 (straight 18-8). Annealing at 1040°C. had a markedly beneficial effect on all four grades, but stabilizing the annealed steels for 1 hour reduced the bendability of Types 347, 301 and 310, leaving Type 321 unchanged. Prolongation of the stabilizing treatment to 4 hours made Type 347 equivalent with 321 in bendability, but produced no change in 301 or 310.

Application of the modified bend test to the study of embrittlement of Type 446 (26 per cent. chromium steel), on exposure at 475°C., showed that by this means it is possible to detect embrittlement after exposure of only one hour, whereas specimens which are unnotched require many hours or even days to manifest the change clearly.

Electrochemical Cleaning of Stainless Steel after Welding

'New Way to Clean Stainless.' *Welding Jnl.*, 1951, vol. 30, Mar., p. 271.

Armco Steel Corporation announces development of a simple method for removing weld discoloration from stainless steel: it is particularly useful for cleaning of parts to which access by ordinary methods is difficult.

A copper rod (¼-in. dia.) is bent to a convenient shape, and is tipped with short pieces of rubber tubing, to facilitate handling, and to prevent the copper touching the stainless steel, which would cause short-circuiting. A small amount of 50 per cent. phosphoric acid is poured over the specimen, using just enough acid to contact the copper rod and wet the discoloured area. (A higher concentration of acid may be used; the more concentrated the acid the brighter is the finish produced on the steel.) The copper rod is connected to the negative terminal of a d.c. power source, the stainless steel part to the positive terminal. The copper rod is then passed, at about two feet per minute, along the joint to be cleaned.

Where the weld discoloration extends over a large area, copper strip may be used, wrapped in acid-damped asbestos. Due to the larger contact area, the strip method requires a current of 5-6 amp./sq. in. of strip, but the current density is the same.

Maintenance of Clad Materials

E. H. WYCHE: 'Clad Steel Equipment; Some Hints for Modern Maintenance.' *Chemical Engineering*, 1951, vol. 58, Jan., pp. 122-3.

The increasing use of clad-steel equipment in many industries has focused attention on maintenance procedure which will ensure long life and maximum usefulness. This article, the first of its kind, gives a practical review of likely sources of contamination and of methods of routine cleaning. Some of the main points are summarized below.

Surface contamination may be caused by:—

(1) Iron rust (e.g., from pipelines running above equipment, at pipeline joints or outlets, and by tools dropped on the clad surface).

(2) Collection of sediments, sludge or solid matter from process materials.
(3) Splash spots from above liquid level.
(4) Accumulations of film, grease and dust.
(5) Evaporated and concentrated corrosive products.
(6) Inaccessible areas in contact with graphite, wood, rubber, etc.

A reminder is also given that localized overheating, and use of marking implements containing graphite, sulphur or zinc should be avoided.

Routine cleaning is a *sine quâ non* of long life. Soap and water, bristle-brush scrubbing, fine pumice, solvents and reputable cleaners can be used with safety; some of the modern detergents are better than soap. Ammonia, washing soda, borax and similar materials are also good cleaning agents. Sandblasting (preferably with flint-type sand) is sometimes useful for removing surface iron, scale, weld flux, etc. The sand used must be iron-free. If the surface is to be polished, an iron-free wire brush, or grinding, is preferred.

Recommendations for cleaning stainless-clad and nickel, Monel-, and Inconel-clad steels are given below.

'*Stainless-Clad Steel*

Nitric-acid solutions will not harm unpolished stainless steel surfaces. A 10-20 per cent. solution (made up in paste form with glycol for safety in handling) is usually sufficient to dissolve mineral deposits. More dilute solutions may be effective for dissolving iron stains. Loose iron can be removed by swabbing down with 5-10 per cent. nitric acid by volume at room temperature. Wash off with clean water. *Warning*: No fittings of carbon steel, brass, copper, bronze, nickel or any other material which is soluble in nitric acid should be allowed to come in contact with this acid. Even a brief contact with nitric acid is detrimental to such parts. Protection for skin, eyes, clothing should be provided.

'The following alternative solution can be used for pickling and removal of scale from stainless-clad surfaces:—

Sulphuric acid (commercial, sp. gr. 1·84)—10 parts by weight.
Rock salt—7-10 parts by weight.
Water to make 100 parts by weight.
Operating temperature 150°-160°F.

This solution is very strong, quite rapid in action and should be used only with extreme care. Thorough washing with clear water should follow.'

'*Nickel-, Monel- and Inconel-Clad Steel*

For removing loose iron from the surfaces of nickel-clad, Inconel-clad or Monel-clad vessels the following procedure will be useful:

Hydrochloric acid (20° Bé)—31 cc.
Ferric chloride—42·5 g.
Water—1000 cc.

'*Caution*: this solution should be used cold and not left in contact with the surface for more than an hour, since its action is rapid. Thorough rinsing should follow.

'For cleaning polished surfaces a paste made with either magnesium oxide or finely powdered pumice can be used if an extremely fine polishing action is required. If a more strongly abrasive effect is required, iron-free emery of 180 grit, lubricated with kerosene or lard oil, is recommended. A 5-10 per cent. nitric-acid solution, with 1-2 per cent. sodium bichromate, to prevent discoloration, may also be used.

'Fingerprints, smears, grime, etc., on polished surfaces should be removed with ordinary solvents, a good detergent, or soap and water. Liquid and other metal 'polishes' should be used only with extreme caution.'

Corrosion-Resistance of Copper and Copper-base Alloys

'Corrosion Resistance of Copper and Copper Alloys.' *Chemical Engineering*, 1951, vol. 58, Jan., pp. 108-12.

The article summarizes, on a qualitative basis, information on the corrosion-resisting characteristics of copper and its alloys, and some of the resulting applications.

Part I. A condensed survey of the effects of the following types of corrosive on these materials: acids, alkalis, ammonia, salt solutions, gases, organic compounds, fresh and sea waters, food products, corrosives encountered in petroleum plants, steam.

Part II. Chart, rating typical brass, bronze, cupro-nickel and nickel silver alloys in four gradings, with regard to their suitability or limitations, in handling a wide range of corrosives. It is emphasized that the ratings must be considered only relative and should not be treated as a basis for selection under specific conditions of service.

Part III. Table showing compositions of commercial forms of copper, brass, leaded brass, special brasses, phosphor-bronze, aluminium- and cadmium-bronzes, copper-silicon alloys, cupro-nickel and nickel silver.

Some typical uses of copper alloys in the following industries are listed: breweries, distilleries, gas industry, oil refineries, organic-chemical-handling plant, pulp and paper mills, salt-manufacturing plant, sugar processing.

Attention is drawn to the fact that many of the names of materials mentioned in The Nickel Bulletin are *Registered Trade Marks*.

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